GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 7/19/78

Project Title: Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements

Project No: E-21-629

Project Director: Dr. E. B. Joy

Sponsor: National Science Foundation

Agreement Period: From 7/1/78 Until 12/31/79 (Grant Period)

Type Agreement: Grant No. ENG 78-01587

Amount: $17,500 NSF
4,115 GIT (E-21-325)
$21,615

Reports Required: Annual Progress Report (if 2nd increment of funding is awarded); Final Technical Report; Summary of Completed Project

Sponsor Contact Person (s):

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Defense Priority Rating: N/A

Assigned to: Electrical Engineering (School/Laboratory)

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CA-3 (3/76)

A INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 10/5/81

Project Title: Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements

Project No: E-21-629

Project Director: Dr. E. B. Joy

Sponsor: National Science Foundation

Effective Termination Date: 2/28/81

Clearance of Accounting Charges: 2/28/81

Grant/Contract Closeout Actions Remaining:

- [ ] Final Invoice and Closing Documents
- [x] Final Fiscal ~~Report~~ Accounting (FCTR)
- [x] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______

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FORM OCA 10:781

E-21-629 /Joy
Submitted w/ proposal 6/27/79

Progress Report
National Science Foundation Grant No. ENG78-01587

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

Introduction

The research program has as its overall goal, the determination of the accuracy of calculating far field antenna patterns from measurements made in the near field of the antenna. Specifically the near field measurements are taken over a finite portion of a planar surface located near the antenna. Past research in the area of near field antenna measurements have demonstrated imperically that accuracies greater than or equal to the best far field range measurements can be achieved for high gain antennas if the near field measurement area is greater than two and one half times the antenna aperture and that the measurement area includes all near field values with amplitudes greater than 45 dB below the peak near field value. These criteria, however offer no guarantee of accuracy in all cases, and at best are only applicable to high gain antennas with single main beams such that the near field energy is concentrated in a single localized area on the planar measurement surface. The criteria are also very costly in measurement facilities and measurement time as the measurement facility and the number of measurements must in proportion to two and one half times the antenna aperture area, not the aperture area itself. Thus a rigorous, generally applicable, accuracy bound is needed to allow the use of smaller measurement areas with known far field pattern accuracy relationships. Thus for a given desired accuracy the near field measurement procedure could be specified.

Initial Investigation

The far field radiation pattern of an antenna is proportional to the two dimensional Fourier transform of the near field distribution of the antenna specified on a planar surface. Initial effort was devoted to the investigation of two general approaches for determining the Fourier transform of a finite set of sampled data. The first approach was expansion of the finite set of sampled data as a summation of prolate spheroidal wave functions and then extrapolation of this summation to the unsampled portion of the plane and subsequent computa-

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tion of the Fourier transform of the extrapolated summation. The second approach was the windowing of the finite set of sampled data to smooth the discontinuity at the edge of the finite measurement window followed by computation of the Fourier transform of the windowed data. Such classic window functions as the Hanning, Hamming and the general class of Blackman windows were used. Although the window functions do greatly reduce the effects of data truncation at the edges of the measurement window, they have no extrapolative powers to "analytically continue" the measurements, resulting in large far field pattern error bounds. Thus it has been concluded that windowing the data is not helpful in determining the accuracy of calculated far field patterns from near field measurements.

Prolate Spheroidal Expansion

The prolate spheroidal expansion of the finite set of sampled near field measurement data was found to lead to an upper bound on the accuracy of far field radiation patterns determined from spatially limited near-field measurements.

The error in determining the far field radiation pattern from the prolate spheroidal expansion results from two sources. The first source is the spatial truncation of the near field measurement data to a finite portion of the plane. Results can be found in the literature which will lead to an error bound for the Fourier transform of such a spatially limited calculation if the function being transformed is also limited in the Fourier transform domain. Luckily electromagnetic near field distributions are bandlimited in the transform domain. The second source of error is the sampling of the near field distribution at sample spacings specified by the Nyquist criterion as applied to planar electromagnetic fields. The Nyquist criterion is only valid if the entire planar surface is sampled and does not apply if only a finite portion is sampled. Thus this research has been devoted to formulating the error due to sampling a finite portion of the planar surface and incorporating this formulation into the error bounds for determining the Fourier transform of a two dimensional, spatially limited planar distribution fitted with a two dimensional prolate spheroidal expansion. Such an upper bound has been found. The upper bound was found to be a function of the percentage of power measured in the finite region of the measurement plane compared to the amount of total power passing throughout the infinite near field measurement plane. No error is made in the computation of the far field radiation patterns for the case in which 100% of the power is measured and infinite error is made in the case of zero measured power. Although the theory and technique for the resulting upper bound of the error are general, the upper bound is dependant on the antenna pattern being measured and thus a specific percentage of power can not aprior be specified. For most cases however the percentage of power required for acceptable error appears to be in the range from 85 to 95% of the total power. An initial report of this work has been submitted for presentation at the National Radio Science Meeting, November 5-8, 1979 in Boulder, Colorado. Copies of the submitted abstract are attached.

Work Remaining

Work is now underway to determine the amount of power measured in the measurement window versus the total power crossing the measurement plane. For high gain, lossless antennas the total power is approximately equal to the power input to the antenna. A more general method of determining this power, however, is the computation of the power from the extrapolated prolate spheroidal expansion of the spatially limited measurement. In this case however there is an error in determining this power which is related to the error bound being sought. Although the error in determining the total power has only a second order effect on the error bound for the radiation pattern for most practical measurement situations, this error must be established.

The measurement portion of the research program in which near field distributions of varying spatial extent are measured, error bounds determined, far field patterns calculated and compared with the same patterns measured on a far field range has not begun. Also, only a small beginning has been made to publish this work in the open literature. These three remaining efforts are described in the accompaning proposal for continuation of this research.

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS:

T.S. Craven and E.B. Joy, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA 30332

The problem of determining the sampling window truncation error in calculating the far field radiation pattern of an antenna from near-field measurements made over a finite portion of a planar surface located near the antenna is discussed. The method of determining the error is not restricted to a specific type of antenna, but applies to a broad, general class of antennas.

Three things are known about the planar near field of an antenna which help in determining this error. First, the total power on the infinite near-field plane is finite. Secondly, the near-field plane is located a finite distance from the antenna so that the higher order evanescent modes have attenuated and the near field is approximately bandlimited in the Transform domain. Third, the field attentuates as 1/r as r approaches infinity. It is known that such a bandlimited finite power function can be reconstructed outside a finite window by expressing the function as a summation of prolate spheroidal wave functions fitted to the function within the window and that such a summation approaches 1/r as r approaches infinity. By expressing the measured near field as such a summation, an expression is obtained for the error. An upper bound on this error is obtained as a function of the ratio of power measured to the total power by using the method of Lagrangian Multipliers. The total power passing through the infinite measurement plane is bounded by measuring the input power to the test antenna.

The method has been tested by measuring the near-field of an S-band antenna over a large near-field sampling window. The far-field was then calculated using the standard procedure. The near-field data was then truncated to two smaller window sizes and the far field calculated from the truncated data. The error bound was then calculated using the method described above. The actual error was determined by comparing the far field calculated from the truncated sampling windows with the far field calculated from the full size sampling window data. The far field of the antenna was also measured on a conventional far-field range and the calculated far field was compared to the measured far field. The results of these tests will be presented.

This material is based on work supported by the National Science Foundation under Grant No. ENG78-01587

E-21-629

Progress Report

National Science Foundation Grant No. ENG 78-01587

Period: June 1979 - June 1980

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

INTRODUCTION

Near-field antenna measurements offer a practical example of a fundamental question in Fourier analysis: What is the error in determination of the Fourier transform of a bandlimited signal when only a sampled portion of the signal is known? Planar near-field antenna measurements are performed by sampling the electromagnetic field radiated by an antenna on a planar surface close to the antenna. Ideally, the entire surface should be sampled. No fundamental error in the computation of the Fourier transform would be made if the entire plane were sampled at the two-dimensional Nyquist rate. However, it is not possible to sample the entire plane and an error is made by the spatial truncation of the measurements. If the measurements were continuously made the resulting error in the calculated Fourier transform can be shown to be a convolution of the true Fourier transform with the Fourier transform of the rectangular window function. Recovery of the true Fourier transform might be possible using two-dimensional deconvolution techniques. The measurements are, however, not continuous, but are sampled at the Nyquist rate. The sampling complicates the analysis as the sampling functions assume knowledge of measurements outside the measurement window.

EARLY WORK

The first year effort was devoted to the search for alternate sampling functions, primarily the Prolate Spheroidal Expansion. Some progress was achieved as reported in the first progress report, and work is continuing.

LATEST WORK

The last year's effort has been directed toward development of a "iterative deconvolution" technique. This technique was originally suggested by Papoulis in his paper "A New Algorithm in Spectral Analysis and Band-Limited Extrapolation." Early investigation of the technique showed that it worked for strictly bandlimited, mathematical functions, but did not work for measured data. Effort is now concentrating on adding information contained in electromagnetic theory to the extrapolation processes.

The basic iterative technique as posed by Papoulis was to surround the spatially truncated data with zeros, perform a Discrete Fourier Transform (DFT), set DFT values whose transform coordinates were larger than the assumed band limit equal to zero, perform an inverse DFT, and reset values within the measured window to measured values. Repetition of this process, hopefully converged to an extrapolated version of the truncated data. The only additional information required was the two-dimensional bandlimits. This process is obviously not unique as many bandlimited finite data sets have identical center sequences. Error bounds on this technique must be infinite. However, experimentation with this technique on the two-dimensional sinc function and on the Blackman window functions showed that 90% of the energy in the functions could be predicted from 60% of the energy, a surprising result. Typically 5 to 10 iterations were sufficient for good results.

Application of this technique to measured data, generally was not successful. Even after 50 and 100 iterations, the technique was slowly converging on what appeared to be the wrong answer.

Work is now underway to add additional information regarding both the data and its Fourier transform. Typical types of information include:

1. Known finite total power contained in the extrapolated data.
2. Distance data behavior approaching the radiation condition: 1/r.
3. Fourier transform exponential decay above the free space wave-number.
4. Amplitude patterns of the Fourier transform.

WORK REMAINING

Addition of the above information types to enhance accuracy of the extrapolation technique.

E-21-629

NATIONAL SCIENCE FOUNDATION Washington, D.C. 20550	**FINAL PROJECT REPORT** NSF FORM 98A	
PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING		
PART I—PROJECT IDENTIFICATION INFORMATION		
1. Institution and Address Georgia Institute of Technology Atlanta, GA 30332	2. NSF Program Research Grant	3. NSF Award Number ENG 78-01587
	4. Award Period From 7-1-78 To 2-28-81	5. Cumulative Award Amount $40,099
6. Project Title Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements		

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

This project examined the fundamental problem of estimating the Fourier transform of a two-dimensional process from a limited set of samples from this process. The process was known to be bandlimited in the Fourier transform sense and samples are taken at the Nyquist rate. This project showed that the Fourier transform of this process could not, in general, be accurately determined from this limited information. The Fourier transform of some strictly bandlimited functions could be accurately determined when as little as 60% of the energy content of the process was sampled. The Fourier transform of measured processes could not be accurately estimated, however, without the addition of some outside information.

A technique was developed for the accurate estimation of the Fourier transform from limited data when a basic model of the electromagnetic device or field was added to the computation. Neither the model or the computation process was in itself sufficient. Together, however, the Fourier transform could be accurately determined.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (√)	Approx. Date
a. Abstracts of Theses		X			
b. Publication Citations		X			
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results		X			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Edward B. Joy		9-4-81

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS

by

E. B. Joy

School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Final Technical Report

National Science Foundation Grant
ENG 78-01587

August 1981

INTRODUCTION

The research program had as its overall goal, the determination of the accuracy of calculating far-field antenna patterns from measurements made in the near-field of the antenna. Specifically the near-field measurements are taken over a fininte portion of a planar surface located near the antenna. Past research in the area of near-field antenna measurements have demonstrated imperically that accuracies greater than or equal to the best far-field range measurements can be achieved for high gain antennas if the near-field measurement area is greater than two and one half times the antenna aperture and that the measurement area includes all near-field values with amplitudes greater than 45 dB below the peak near-field value. These criteria, however, offer no guarantee of accuracy in all cases, and at best are only applicable to high gain antennas with single main beams such that the near-field energy is concentrated in a single localized area on the planar measurement surface. The criteria are also very costly in measurement facilities and measurement time as the measurement facility and the number of measurements must in proportion to two and one half times the antenna aperture area, not the aperture area itself. Thus, a rigorous, generally applicable, accuracy bound is needed to allow the use of smaller measurement areas with known far-field pattern accuracy relationships. Thus, for a given desired accuracy the near-field measurement procedure could be specified.

FUNDAMENTAL QUESTION

The fundamental question, which spans many engineering disciplines, is: can the Fourier transform of a bandlimited continuous process of infinite extent be accurately determined from a finite set of samples of this process, where the samples are taken at the Nyquist rate within the measurement "window?"

PROLATE SPHEROIDAL WAVE FUNCTION APPROACH

The answer to the fundamental question posed above is: no. Either the measurement window must span the entire process or additional information must be used in the determination of the Fourier transform. The electromagnetics of this problem (other disciplines would need to use the basic equations which the field being measured must obey) show that electromagnetic fields must obey at least these three conditions:

1. The total energy in the field being measured is finite;
2. The field being measured is exponentially bandlimited; and
3. The fields being measured decrease as 1/r when the distance from the source r approaches infinity.

These three conditions suggested the use of prolate spheroidal wave functions as the sampling functions rather than the usual sinc functions. The attached abstract of our paper in the Proceedings of the National Radio Science Meeting, Boulder, Colorado, November 1979, details the results of this technique. In summary, when the percentage of the energy measured was known, an upperbound on the error in the calculated Discrete Fourier Transform (DFT) can be obtained. Typically, good error bounds required greater than 90% of the total energy be measured.

ITERATIVE EXTRAPOLATION

A technique originally described by A. Papoulis in, "A New Algorithm in Spectral Analysis and Band-Limited Extrapolation," IEEE Trans. on Circuits and Systems, Vol. CAS-22, No. 9, September 1975, has been implemented and modified. Papoulis's technique was shown to extrapolate spatially limited data, but only for strictly bandlimited, mathematical functions and was shown to produce unacceptable results on measured data. Additional information was found to be needed to yield accurate results.

The addition of the three conditions stated above, only marginally improved the basic extrapolation process. It did, however, confirm the accuracy bounds derived earlier with the Prolate Speroidal Wave Functions. The attached abstract of our "Signal Processing in Electromagnetic Radiation Measurements," in the Proceedings of the IEEE International Circuits and Systems Symposium, Chicago, Illinois, April 27-29, 1981 presents some of the results of this research.

NEAR-FIELD, FAR-FIELD EXTRAPOLATION

An outgrowth of the above research on iterative extrapolation was the ability to extrapolate with high accuracy the near-field distribution of an antenna when a finite portion of the near-field distribution is known and the two principal plane amplitude cuts of the DFT are known. The modified extrapolation process not only extrapolates the near-field distribution in amplitude and phase but also accurately calculates the amplitude and phase of the DFT. A paper describing this technique is currently being prepared. An important application for this technique exists in antenna/radome analysis where measured far-field amplitude only cuts are known (these are directly related to the DFT of the near-field distribution) and the field in the aperture of the antenna is known. The technique developed on this project then allows calculation of the rest of the planar surface fields and the DFT.

ACCURACY OF RADIATION PATTERNS DETERMINED FROM SPATIALLY LIMITED NEAR-FIELD MEASUREMENTS:
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This material is based on work supported by the National Science Foundation under Grant No. ENG78-01587

SIGNAL PROCESSING IN ELECTROMAGNETIC RADIATION MEASUREMENTS*

Edward B. Joy

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ABSTRACT

Applications of multidimensional digital signal processing techniques to electromagnetic radiation measurements and analysis are presented. Far field and near field radiation measurements and associated signal processing requirements are discussed. On-going signal processing efforts are mentioned.

INTRODUCTION

Electromagnetic radiation measurements are performed for a variety of reasons and over an extremely large frequency range. The primary application of radiation measurement is for the determination of antenna far field patterns. Other applications include measurement of radiation levels for biological safety and electromagnetic interference.

NEAR FIELD ANTENNA MEASUREMENTS

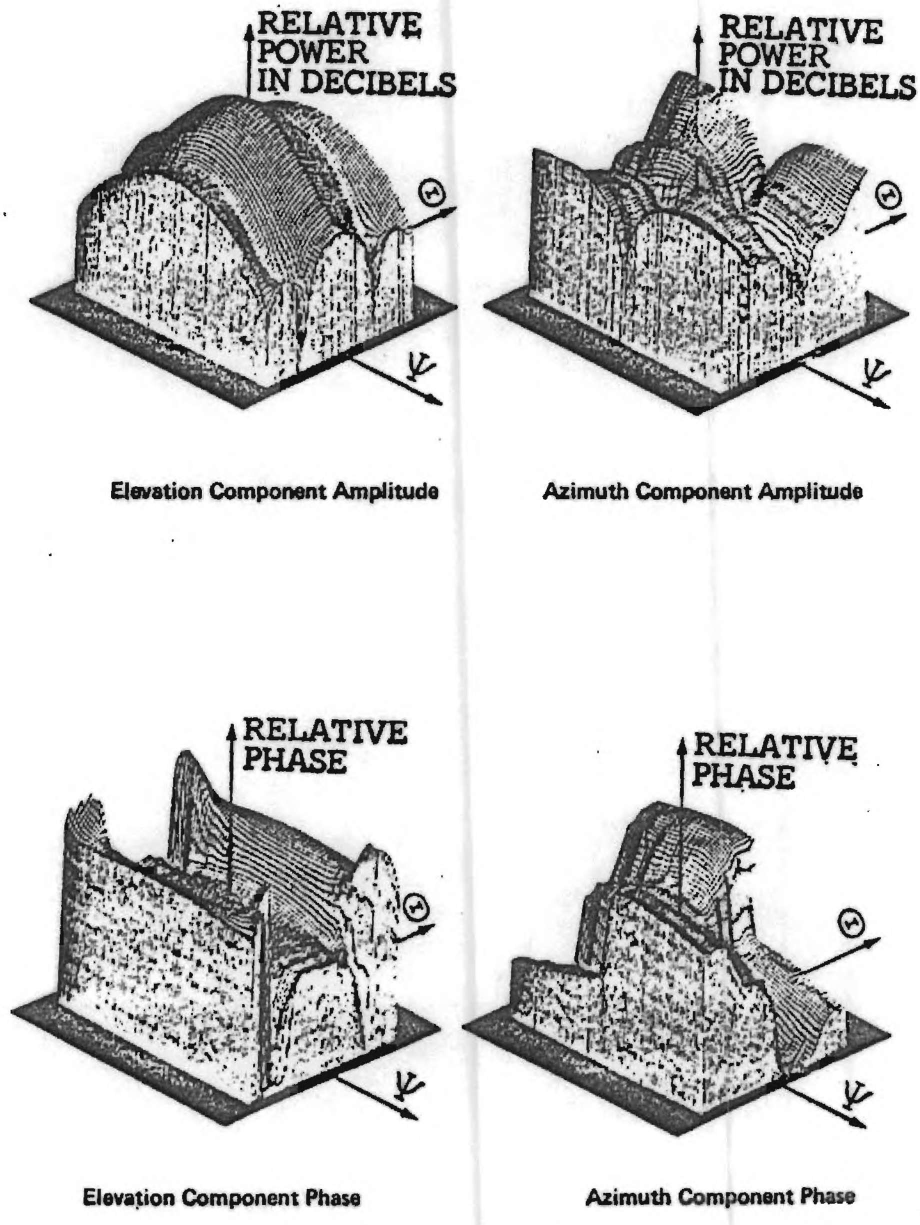
The distance from the antenna to the far field of an antenna required to perform direct far field radiation measurements becomes excessive as the size of the antenna increases and the wavelength decreases. Another approach for far field determination made practicle in part by computers and digital signal processing, is the measurement of near field radiation and the subsequent calculation of the far field. Several factors enter into the measurement and subsequent data processing of near field radiation. First, the probe antenna used to measure the near field radiation, distorts the near field being measured. The distortion effects have been rigorously analyzed and amount to a spatial convolution of the near field radiation being measured and the equivalent near field radiation distribution of the probe antenna. The signal processing effort is then to deconvolve these two two dimensional vector distributions. The vector deconvolution is easily performed in the wavenumber domain. Apriori knowledge or measurement of the far field radiation pattern of the probe antenna is required for the determination of the wavenumber spectrum of the probe. Figure 1 shows such a set of two dimensional far field antenna patterns of a small horn antenna. These graphs are plotted versus elevation and azimuth. The amplitude scale is in decibels from zero to -60 decibels. The phase scale covers a range of 360 degrees. Second, the near field must be sampled on a surface enclosing the test antenna. The surface is usually near the antenna to minimize the surface area and measurement data. It has been shown that the wavenumber spectrum, the two dimensional Fourier transform of a planar electromagnetic field distribution, is band-limited to a circular region. A square sampling lattice of spacing less than one half wavelength is required to prevent aliasing. Figure 2 shows two components of the electric field tangential to the measurement plane. The amplitude scales are in decibels from zero to -40 decibels. The phase measurement scale covers the full 360 degree range. Third, the measurement surface, in this case the planar surface, must be geometrically perfect to within approximately one two hundredeth of a wavelength to yield accurate results. Deviations of nonideal surfaces must be measured and used in computation of the far field pattern. Figure 3 shows an actual measurement surface. Compensating for such two dimensional positional error distributions results in a major signal processing effort. The effort involves performing numerous two dimensional Fourier transforms of the electromagnetic fields and the surface and inverting a matrix of N^2 by N^2 elements where N is the total number of two dimensional near field measurements.

Figure 4 shows the amplitude of the far field elevation component of a 10 GHz off-set-feed parabolic dish antenna calculated from near field measurements. The accuracy to which the far field patterns of an antenna can be obtained using the near field measurement technique has been demonstrated to be equal to or superior to high quality far field measurements and is now being used for the acceptance testing of some large military radar system antennas.

ON-GOING SIGNAL PROCESSING EFFORTS

Several multidimensional signal processing efforts are under way to enhance the near field measurement technique. These include: (1) hexagonal sampling of the planar near field radiationed to save measurement and computation time, (2) near field measurement extrapolation to reduce the number and spatial extent of measurement, and (3) application of signal processing techniques to the cylindrical and spherical near field measurement surfaces.

*The near field radiation measurement work at Georgia Tech is currently being supported by the National Science Foundation, the U.S. Army Research Office, Durham, the Joint Services Electronics Program and Scientific Atlanta, Inc.



Elevation Component Amplitude

Azimuth Component Amplitude

Elevation Component Phase

Azimuth Component Phase

Figure 1. Far Field Amplitude and Phase Patterns of Horn Antenna

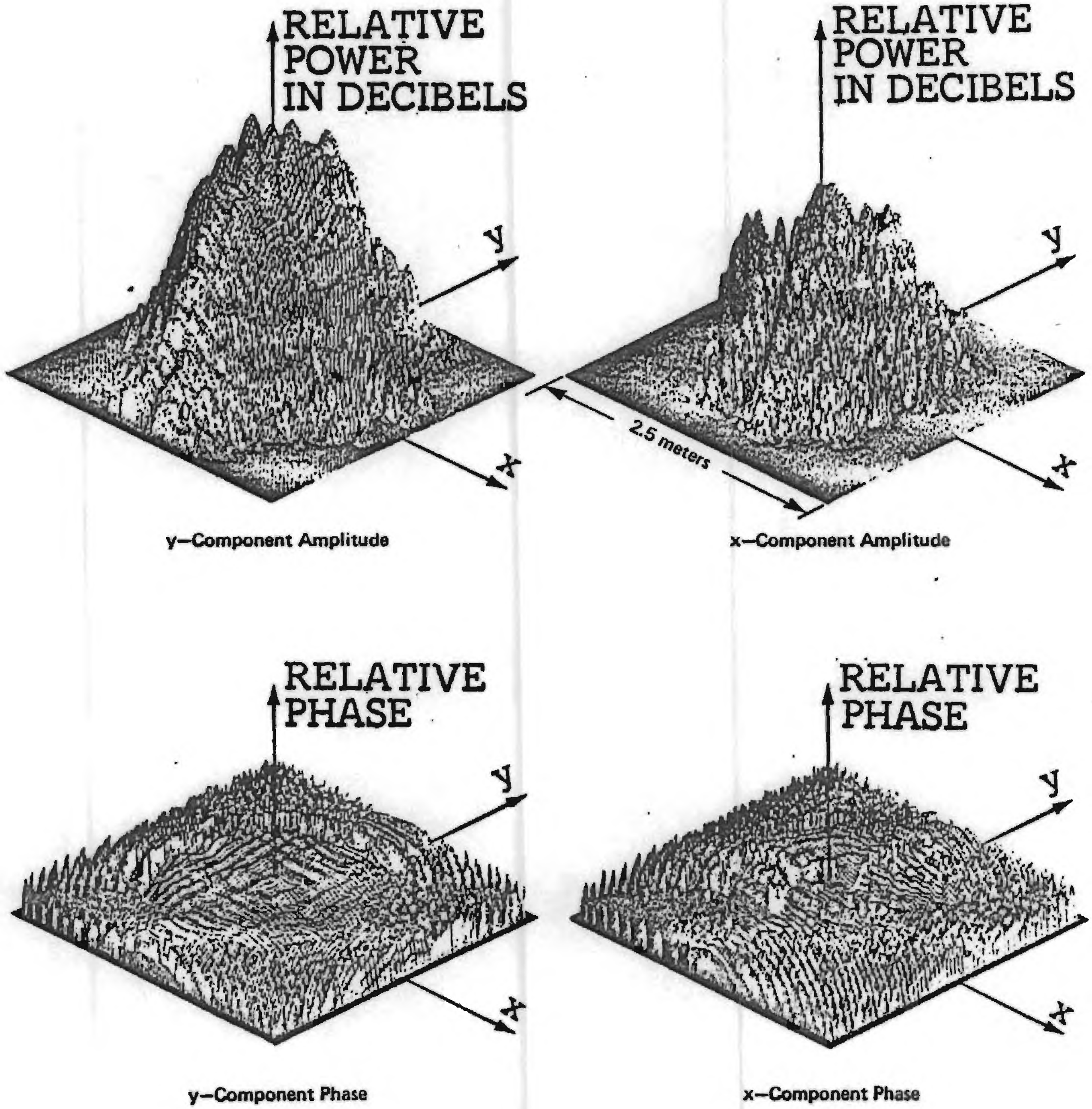


Figure 2. Near Field Radiation Measurements

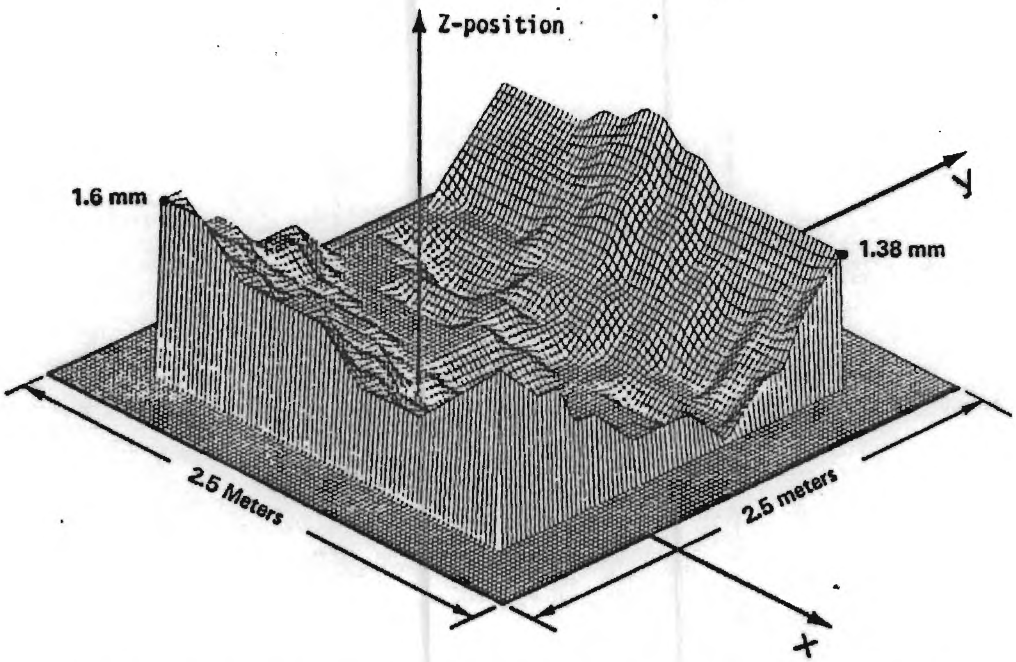


Figure 3. z—Position of Near Field Measurement Probe Within Planar Measurement Area

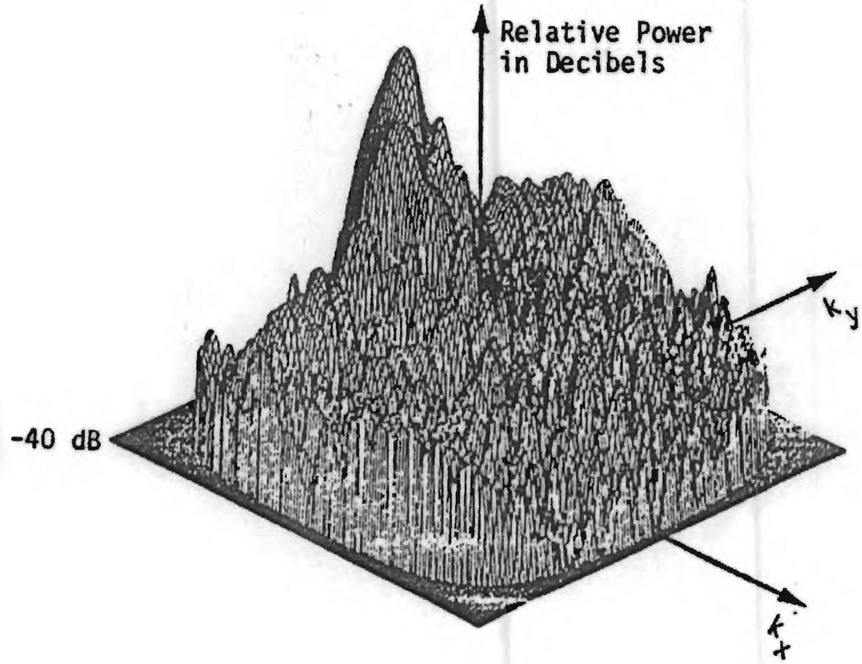


Figure 4. Amplitude of the Calculated Far Field Elevation Component

THESES

Mr. T. S. Craven's Ph.D. Dissertation research entitled:

"Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements," is currently in progress.

Mr. A. D. Dingsor's Master Degree Thesis entitled:

"Computer Simulation of Cylindrical Surface Near-Field Measurement System Errors," was completed in August 1979.

SCIENTIFIC COLLABORATORS

Principal Investigator: Dr. Edward B. Joy (See attached Biographical Sketch)

Faculty Investigator: Dr. Gene K. Huddleston (See attached Biographical Sketch)

Graduate Research Assistants:

Mr. Tyson S. Craven

Mr. Andrew D. Dingsor

Mr. Bruce Eisenman

BIOGRAPHICAL SKETCH

JOY, EDWARD B. - Professor of Electrical Engineering
Georgia Institute of Technology

EDUCATION

B.E.E., Georgia Institute of Technology	1963
M.S.E.E., Georgia Institute of Technology	1967
Ph.D., E.E., Georgia Institute of Technology	1970

EMPLOYMENT HISTORY

AAI, Electronic Design Engineer	Summer 1963
U. S. Navy, Electrical Division Officer	1963-1965
Jacksonville Shipyards, Electrician	Summer 1966
Advanced Research, Inc., Research Engineer	Summer 1967
Georgia Institute of Technology	
Schlumberger Fellow	1966-1967
NASA Fellow	1967-1968
Scientific Atlanta Fellow	1968-1969
Research Assistant	1969-1970
Assistant Professor of Electrical Engineering	1970-1975
Associate Professor of Electrical Engineering	1975-1980
Professor of Electrical Engineering	1980-present

CURRENT FIELDS OF INTEREST

Electromagnetic field analysis and measurement; radome analysis and design; underground power distribution and grounding systems; lightning measurement and protection.

THESIS AND DISSERTATION

1. E. B. Joy, "An Electronics Feedback System for Amplitude Stabilization of a Helium Neon Gas Laser," Master's Thesis, Georgia Institute of Technology, 1967.

2. E. B. Joy, "Spatial Sampling and Filtering in Near-Field Measurements," Ph.D. Dissertation, Georgia Institute of Technology, 1970.

PUBLICATIONS

1. E. B. Joy and D. T. Paris, "Spatial Sampling and Filtering in Near-Field Measurements," IEEE Transactions on Antennas and Propagation, Vol. AP-20, No. 3, May 1972, pp. 253-261.

2. E. B. Joy and D. T. Paris, "A Practical Method for Measuring the Complex Polarization Ratio of Arbitrary Antennas," IEEE Transactions on Antennas and Propagation, Vol. AP-21, No. 4, July 1973, pp. 432-435.

3. (Invited) D. T. Paris, W. M. Leach, and E. B. Joy, "Basic Theory of Probe Compensated Near-Field Measurements," IEEE Transactions on Antennas and Propagation, Vol. AP 26, No. 3, May 1978, pp. 373-379.

4. (Invited) E. B. Joy, W. M. Leach, D. T. Paris, and G. P. Rodrigue, "Applications of Probe Compensated Near-Field Measurement," IEEE Transactions on Antennas and Propagation, Vol. AP-26, No. 3, May 1978, pp. 379-389.

5. H. N. Nunnally, E. B. Joy, R. P. Webb, and A. P. Meliopoulos, "Computer Simulation for Determining Step and Touch Potentials Resulting From Faults or Open Neutrals in URD Cables," IEEE Transactions on Power Apparatus and Systems, Paper F78 694-2, Vol. PAS-98, No. 3, May/June 1979, pp. 1130-1136.

6. L. E. Corey and E. B. Joy, "On Computation of Electromagnetic Fields on Planar Surfaces from Fields Specified on Arbitrary Surfaces," accepted for publication in the IEEE Transactions on Antennas and Propagation.

7. A. P. Meliopoulos, R. P. Webb, and E. B. Joy, "Analysis of Grounding Systems," IEEE Transactions on Power Apparatus and Systems, Paper F80 274-1, Vol. PAS-100, No. 3, pp. 1039-1048.

8. A. P. Meliopoulos, R. P. Webb, and E. B. Joy, "Computer Simulation of Faulted URD Cables: Analysis and Results," IEEE Transactions on Power Apparatus and Systems, Paper F81, Vol. PAS-100, No. 4, pp. 1545-1552.

MISCELLANEOUS ARTICLES

1. (Invited) E. B. Joy and D. G. Bodnar, "Near-Field Antenna Measurement Activities at Georgia Tech," Feature article in IEEE Antennas and Propagation Society Newsletter, Vol. 21, No. 2, April 1979, pp. 5-7.

2. E. B. Joy and D. G. Bodnar, "Antenna Near-Field Measurements Summarized," Review of recent research and development in Microwave and Laser Technology, Vol. 18, No. 6, June 1979, p. 33.

CONFERENCE PROCEEDINGS

1. E. B. Joy and D. T. Paris, "Spatial Sampling and Filtering in Near-Field Measurements," Proceedings of the Conference on Precision 1970, p. 61.Electromagnetic Measurements - 1970, Boulder, Colorado, June 2-5,

2. E. B. Joy, D. T. Paris, and W. M. Leach, "Spatial Sampling and Filtering in Near-Field Measurements," Proceedings of the Spring Meeting USNC/URSI, Washington, D. C., April 8-10, 1971, p. 15.

3. E. B. Joy, "Far Field Calculation from Near-Field Measurements," Proceedings of the Eleventh Symposium on Electromagnetic Windows, Atlanta, Georgia, August 1972, pp. 184-188.

4. E. B. Joy, C. P. Burns, and G. P. Rodrigue, "A Study of the Accuracy of Far-Field Patterns Based on Near-Field Measurements," Proceedings of the 1973 IEEE/G-AP International Symposium, August 22-24, 1973, pp. 57-60.

5. E. B. Joy, W. M. Leach, and D. T. Paris, "Probe Compensated Near-Field Measurements: Basic Theory, Numerical Techniques, Accuracy," Proceedings of the 1974 International IEEE AP-S/URSI Symposium, June 10-12, 1974, pp. 155-157.

6. E. B. Joy, "Near Field Measurement Technique for Millimeter Wavelengths," Report of the ARPA/TRI-SERVICE Millimeter Wave Workshop, December 16-18, 1974, pp. 33-42.

7. E. B. Joy, C. P. Burns, G. P. Rodrigue, and E. C. Burdette, "Accuracy of Hemispherical Far-Field Patterns Determined from Near-Field Measurements," Proceedings of the 1975 IEEE/AP-S International Symposium, June 2-4, 1975, pp. 224-227.

8. E. B. Joy and L. E. Corey, "The Use of Lightning to Measure the Electromagnetic Penetration of Large Structures," DNA System Level Testing Seminar, Palo Alto, California, September 2-11, 1975.

9. E. B. Joy, "The Use of Lightning to Measure the Electromagnetic Penetration of Large Structures," Proceedings of the 1975 IEEE Electromagnetic Compatibility Symposium, Paper 3AId, San Antonio, Texas, October 7-9, 1975.

10. E. B. Joy, "Maximum Near Field Measurement Error Specification," Proceedings of the 1977 IEEE/AP-S International Symposium, San Francisco, California, June 20-24, 1977, pp. 390-393.

11. (Invited) E. B. Joy, W. M. Leach, Jr., D. G. Bodnar, C. P. Burns, F. L. Cain, J. L. Edwards, R. C. Johnson, and C. E. Ryan, "Near-Field Measurement Applications and Current Research at Georgia Tech," Proceedings of the National Radio Science Meeting, Boulder, Colorado, January 9-13, 1978.

12. L. E. Corey and E. B. Joy, "One Dimensional Analysis of the Effects of a Warped Near-Field Measurement Surface on Calculated Far-Field Antenna Patterns," Proceedings of the 1978 SOUTHEASTCON, April 10-12, 1978, Atlanta, Georgia.

13. E. B. Joy, W. J. Barnes, A. P. Meliopoulos, H. N. Nunnally, R. P.Webb, and R. E. Wilson, "Multi-layer Method of Moments Analysis of Earth Grounding Systems," Proceedings of the SOUTHEASTCON '78, Atlanta, Georgia, April 10-12, 1978, pp. 12-14.

14. L. E. Corey and E. B. Joy, "Analytical Compensation for the Effects of a Warped Planar Near-Field Measurement Surface on Calculated Far-Field Antenna Patterns," Proceedings of CPEM '78, Ottawa, Canada, June 26-27, 1978, pp. 126-127.

15. H. N. Nunnally, E. B. Joy, R. P. Webb, and A. P. Meliopoulos, "Computer Simulation for Determining Step and Touch Potentials Resulting From Faulted or Open Neutrals in URD Cables," Proceedings of the IEEE PES Summer Meeting, Los Angeles, California, July 16-21, 1978, paper F78 694-2.

16. E. B. Joy, A. P. Meliopoulos, and R. P. Webb, "Touch and Step Calculation for Substation Grounding Systems," Proceedings of the IEEE PES Winter Meeting, New York, New York, January 1979, paper A79 052-A.

17. A. P. Meliopoulos, D. P. Rudolph, R. P. Webb, and E. B. Joy, "URD Cable Analysis to Determine Shield and Earth Potentials in Normal and Abnormal Operating Conditions," Proceedings of the SOUTHEASTCON '79, Roanoke, Virginia, April 1-4, 1979, pp. 394-398.

18. L. E. Corey and E. B. Joy, "Far-Field Antenna Calculation from Near-Field Measurements Including Compensation for Probe Positioning Errors," Proceedings of the 1979 IEEE/AP-S International Symposium, Seattle, Washington, June 18-22, 1979, pp. 736-739.

19. E. B. Joy and A. D. Dingsor, "Computer Simulation of Cylindrical Surface Near-Field Measurement System Errors," Proceedings of the 1979 IEEE/AP-S International Symposium, Seattle, Washington, June 18-22, 1979, pp. 565-568.

20. E. B. Joy and D. G. Bodnar, "Near-field Antenna Measurement Activities at Georgia Tech," Proceedings of the Antenna Measurement Technique Association Meeting, October 17-18, 1979, Atlanta, Georgia, pp.

21. T. S. Craven and E. B. Joy, "Accuracy of Radiation Patterns Determined from Spectrally Limited Near-field Measurements," Proceedings of the National Radio Science Meeting, Boulder, Colorado, November 5-8, 1979, pp.

22. L. E. Corey and E. B. Joy, "On Computation of Electromagnetic Fields on Planar Surfaces from Fields Specified on Arbitrary Surfaces," Proceedings of the 1980 IEEE/AP-S International Symposium, Quebec, Canada, June 2-6, 1980, pp.

23. E. B. Joy, R. E. Wilson, D. E. Ball and S. D. James, "Comparison of Radome Electrical Analysis Techniques," Proceedings of the Fifteenth Symposium on Electromagnetic Windows, Atlanta, Georgia, June 18-20, 1980, pp. 25-29.

24. A. P. Meliopoulos, R. P. Webb, and E. B. Joy, "Analysis of Grounding Systems," Proceedings of the IEEE PES Winter Meeting, New York, New York, January 1980, Paper F80 274-1.

25. A. P. Meliopoulos, R. P. Webb, and E. B. Joy, "Computer Simulation of Faulted URD Cables: Analysis and Results," Proceedings of the IEEE PES Summer Meeting 1981, Minneapolis, Minnesota, July 7-10, 1980.

26. E. B. Joy, "Signal Processing in Electromagnetic Radiation Measurements," Proceedings of the International Circuits and Systems Symposium, Chicago, IL, April 27-29, 1981, pp.

MAJOR RESEARCH REPORTS

1. C. P. Burns, H. A. Ecker, and E. B. Joy, "Shaping Antenna Phase and Amplitude Distributions for Low Sidelobes," Final Report on U. S. Air Force Contract F19628-70-C-1069, February 1971.

2. E. B. Joy and G. K. Huddleston, "Radome Effects on the Performance of Ground Mapping Radar: Theory," Final Report on U. S. Army Missile Command Contract DAAH01-72-C-0598, March 6, 1973, pp. 200. (AD-778-203/0)

3. G. P. Rodrique, E. B. Joy and C. P. Burns, "An Investigation of the Accuracy of Far-Field Radiation Patterns Determined from Near Field Measurements," Final Report on U. S. Army Missile Command Contract DAAH01-72-C-0950, August 1973, pp. 257.

4. E. B. Joy and L. E. Corey, "Evaluation of the Electromagnetic Vulnerability of NORAD Cheyenne Mountain Complex to EMP," Classified Interium Report on U. S. Air Force Contract F30602-72-C-0409, August 7, 1973.

5. E. B. Joy and G. K. Huddleston, "Radome Effects on the Performance of Ground Mapping Radar: Results," Final Report on U. S. Army Missile Command Contract DAAH01-72-C-0598, March 6, 1973, pp. 160.

6. E. B. Joy, G. K. Huddleston, H. L. Bassett and C. W. Gorton, "Analysis and Evaluation of Radome Materials and Configurations for Advanced RF Seekers," Final Report on U. S. Army Missile Command Contract DAAH02-73-0796, December 31, 1973, pp. 95. (AD-774 310/7)

7. E. B. Joy, L. E. Corey and J. D. Norgard, "Use of Lightning to Determine Electromagnetic Penetration of Cheyenne Mountain," Interim Report on U. S. Air Force Contract F30602-72-C-0409, September 15, 1974, pp. 39.

8. G. P. Rodrigue, E. B. Joy, G. K. Huddleston, C. P. Burns, C. E. Burdette and J. Hanfling, "A Study of Phased Array Antenna Patterns Determined by Measurements on a Near-Field Range," Final Report on U. S. Army Missile Command Contract DAAH02-C-0367, March 1975.

9. E. B. Joy, G. K. Huddleston, H. L. Bassett and S. R. Wheeler, "Multipurpose Missile (MPM) High Performance Radome Tradeoff and Development Study," Final Report on Martin Marietta Aerospace Division Contract P.O. No. ZDZ/283105, April 15, 1975, pp. 145.

10. E. B. Joy, L. E. Corey and J. D. Norgard, "The Use of Lightning to Determine Electromagnetic Penetration of Cheyenne Mountain," Interim Report on U. S. Air Force Contract F30602-75-C-0118, December 15, 1975, pp. 96.

11. J. Allen, W. Gajdu, D. Griffin, R. Harrington, R. Heintz, E. B. Joy, J. Lyon and W. Walker, "A Technology Plan for Electromagnetic Characteristics of Advanced Composites," Final Technical ReportRADC-TR-76-206, April 1, 1976, pp. 157.

12. G. K. Huddleston, E. B. Joy, G. P. Rodrigue, C. P. Burns and W. J. Storey, "A Study of Near-Field Data Handling and Probe Design Techniques," Final Report on U. S. Army Missile Command Contract DAAH01-75-C-0953, April 15, 1976, pp. 77.

13. E. B. Joy, G. K. Huddleston, W. M. Leach, R. F. Hochman, J. G. Rinker, M. Marek, and K. J. Bundy, "A High-Current Minesweeping Electrode Investigation," Final Research Report on U. S. Navy Contract N61339-75-C-0122, June 30, 1976.

14. E. B. Joy and L. E. Corey, "Lightning Measurements at Cheyenne Mountain," Interim Research Report on U. S. Air Force Contract F30602-75-C-0118, November 1, 1976, pp. 76.

15. R. F. Hochman, M. Marek, J. G. Rinker, K. J. Bundy, E. B. Joy, G. K. Huddleston, and W. M. Leach, "A Laboratory Testing and Electromagnetic Analysis Program for Carbon Polymer Jacketed and Platinum Plated Electrodes," Final Technical Report on Task HR-18 of U. S. Navy Contract N61339-75-C-0122, January 31, 1977.

16. G. K. Huddleston and E. B. Joy, "Development of Fabrication and Processing Techniques for Laser Hardened Missile Radomes: Radome Electrical Design Analysis," Final Technical Report on Martin Marietta Aerospace Contract No. 573712, April 1977, pp. 93.

17. R. P. Webb, E. B. Joy and H. N. Nunnally, "Computer Program for Determination of Earth Potentials Due to Faults or Loss of Concentric Neutral on URD Cable," Final Research Report on the Electric Power Research Institute project RP797-1, May 1977, pp. 200.

18. E. B. Joy, Larry E. Corey, Gene K. Huddleston and John D. Norgard, "Electromagnetic Pulse Coupling to Underground Systems," Final Technical Report on U.S.A.F. Contract F30602-75-C-0118, December 31, 1977, pp. 223.

19. E. B. Joy, W. M. Leach, G. K. Huddleston, W. J. Barnes, R. E. Wilson, R. F. Hochman, M. Marek, J. G. Rinker and K. J. Bundy, "Final Design and Analysis of High Current Minesweeping Electrodes," Final Technical Report on of U. S. Navy Contract N61339-75-C-0122, January 31, 1978.

20. E. B. Joy, R. E. Wilson, R. F. Hochman, M. Marek, J. G. Rinker and K. J. Bundy, "LMS Electrode Feasibility Study," Final Technical Report on Task HR-43 of U. S. Navy Contract N61339-75-C-0122, 5 July 1978.

21. R. F. Hochman, M. Marek, J. G. Rinker, E. B. Joy, and R. E. Wilson, "A Feasibility Study of Noble Metal Coated Graphite Conductive Polymer Materials for Minesweeping Electrodes," Final Technical Report on Task HR-37 of U. S. Navy Contract N61339-75-C-0122, October 15, 1978, pp. 62.

22. R. F. Hochman, M. Marek, J. G. Rinker, E. B. Joy and R. E. Wilson, "Design Study for High Current Magnetic Minesweeping "S" Cable," Final Research Report on Task HR-48 of U. S. Navy Contract N61339-75-C-0122, 31 May 1979, p. 113.

23. E. B. Joy, A. P. Meliopoulos and R. P. Webb, "Graphical and Tabular Results of Computer Simulation of Faulted URD Cables, Volume I: Theory and Program Documentation," Final Research Report on the Electric Power Research Institute project RP797-2, July 1979, pp. 163.

24. E. B. Joy, A. P. Meliopoulos and R. P. Webb, "Graphical and Tabular Results of Computer Simulation of Faulted URD Cables, Volume II: Computer Results," Final Research Report on Electric Power Research Institute project RP797-2, July 1979, p. 299.

25. R. F. Hochman, M. Marek, J. G. Rinker, E. B. Joy, and R. E. Wilson, "Development of High Current Polymer Minesweeping Electrodes," Final Technical Report on Task HR-01 of U.S. Navy Contract N00612-79-C-8004, April 30, 1980, pp. 117.

26. R. F. Hochman, M. Marek, J. G. Rinker, E. B. Joy, R. E. Wilson, and V. P. K. Tai, "Modified S-3 Noble Metal Feasibility Anode Study," Final Technical Report on Task HR-06 of U.S. Navy Contract N00612-79-C-8004, May 31, 1980, pp. 34.

INVITED SEMINARS

1. E. B. Joy, "Far-Field Antenna Pattern Calculation from Near Field Measurements," IEEE/G-(AP & MIT), Huntsville Section, Huntsville, Alabama, August 1971.

2. E. B. Joy, "Far-Field Determination from Near-Field Measurements," Industrial Near Field Users Seminar, March 1972, Atlanta, Georgia.

3. E. B. Joy, "Accuracy of Far-Field Patterns Determined from Near-Field Measurements," IEEE/G-(Ap & MTT) Atlanta Section, Atlanta, Georgia, June 1973.

4. E. B. Joy, "State-of-the-Art in Near-Field Measurements," National Bureau of Standards Near-Field Workshop," October 6, 1976, Boulder, Colorado.

5. E. B. Joy, "Warped Surface and Spatially Limited Near-Field Measurements," Georgia Tech/Scientific Atlanta Near-Field Workshop, Atlanta, Georgia, December 15, 1976.

6. E. B. Joy, "Electromagnetostatic Analysis of Conductors in Sea Water and in Layered Soil," Georgia Tech School of Electrical Engineering Graduate Seminar, Atlanta, Georgia, January 24, 1977.

7. E. B. Joy, "Application of Near-Field Measurements to Radar Antenna Technology," Joint Services Radar Antenna Technology Board, Atlanta, Georgia, May 18, 1977.

8. E. B. Joy, "EMP Analysis of CMC," RADC Post-Doctoral Program Meeting/ Seminar, Blue Mountain Lake, New York, August 15-18, 1977.

9. E. B. Joy, "The Use of Lightning to Measure the Electromagnetic Penetration of Large Structures," Atlanta IEEE Electromagnetic Compatability Chapter Meeting, Atlanta, Georgia, January 17, 1979.

10. E. B. Joy, "The Use of Lightning to Measure the Electromagnetic Penetration of Large Structures," Georgia Tech School of Electrical Engineering Graduate Seminar, Atlanta, Georgia, February 5, 1979.

SHORT COURSE LECTURES

1. "Microwave Antenna Measurements," Georgia Tech Continuing Education Short Course, Atlanta, Georgia, July 24-28, 1972.

2. "Modern Antenna Measurements," Technology Service Corporation Short Course, Washington, D. C., February 8-10, 1977.

3. "Antenna Design," Technology Service Corporation Short Course, Washington, D. C., June 14-17, 1977.

4. "Modern Antennas," Technology Service Corporation Short Course, Washington, D. C., October 18-21, 1977.

5. "Near-Field Antenna Measurements," Technology Service Corporation Short Course, London, England, May 2-5, 1978.

6. "Near-Field Antenna Measurements," Technology Service Corporation Short Course, Washington, D. C., May 23-25, 1978.

7. "Near-Field Antenna Measurements," Technology Service Corporation Short Course, Vandenburg Air Force Base, Santa Maria, California, September 11-15, 1978.

8. "Modern Antennas," Technology Service Corporation Short Course, New Carrollton, Maryland, November 14-17, 1978.

9. "Modern Antennas," Technology Service Corporation Short Course, Paris, France, May 15-18, 1979.

10. "Radomes," Technology Service Corporation Short Course, Bethesda, Maryland, June 12-15, 1979.

11. "Antenna Design," Technology Service Corporation Short Course, Bethesda, Maryland, October 17-19, 1979.

12. "Substation Grounding," Georgia Tech Continuing Education Short Course, Atlanta, Georgia, March 17-20, 1980.

13. "Radomes," Technology Service Corporation Short Course, San Diego, California, March 25-28, 1980.

14. "Modern Antennas," Technology Service Corporation Short Course, Dallas, Texas, April 14-17, 1980.

15. "Near-field Antenna Measurements," Technology Service Corporation Short Course, Zurich, Switzerland, May 20-23, 1980.

16. "Radomes," Technology Service Corporation Short Course, Zurich, Switzerland, May 26-29, 1980.

17. "Near-field Antenna Measurements," Technology Service Corporation Short Course, Boulder, Colorado, June 24-27, 1980.

18. "Near-field Antenna Measurements," Technology Service Corporation Short Course, China Lake, California, July 22-25, 1980.

19. "Substation Grounding," Georgia Tech Continuing Education Short Course, Atlanta, Georgia, March 17-20, 1981.

20. "Modern Antennas," Technology Service Corporation Short Course, Bethesda, Maryland, June 9-12, 1981.

21. "Radomes," Technology Service Corporation Short Course, Indiana, June 24-26, 1981.

CONSULTING ACTIVITIES

Martin Marietta Aerospace, Orlando, Florida
Radome Design and Analysis

Brooks Air Force Base, San Antonio, Texas
Digitally Controlled Electro-Mechanical Positioner System Design

Southeastern Center for Electrical Engineering Education, Auburn, Alabama
Effects of Lightning on Composite Material Aircraft

Simmons Industries, Atlanta, Georgia
Microwave Heating of Chickens

Scientific Atlanta, Atlanta, Georgia
1. Far Field Pattern Calculation from Near Field Measurement
2. Computer Graphics
3. Electromagnetic Interference

Edward B. Joy - Biographical Sketch

Vertex Systems, Inc., Tucker, Georgia
Lightning Protection of Digital Systems

Dow Badische Company, Williamsburg, Virginia
Electrostatic Shielding of Conductive Clothing

Technology Service Corporation, Silver Spring, Maryland
Lecturer on Antenna Theory, Design and Measurement
Near Field Antenna Measurement Systems

London, Yancey, Clark & Allen, Birmingham, Alabama
Safety of Electrical Equipment

Transit Products Company, Hapeville, Georgia
High Voltage Sparking

Beneke Corporation, Columbus, Mississippi
Microwave and Dielectric Heating of Wood

British Aerospace, LTD., Herts, England
Near Field Antenna Measurements

Lumpkin, Holland, Ray & Upchurch, Tupelo, Mississippi
Safety of Electrical Equipment

Amateur Radio Relay League, Newington, Connecticut
Near-Field and Far-Field Antenna Radiation Versus Antenna Tower Height

Ford Aerospace, Newport Beach, California
Radome Design and Analysis

Mullis, Reynolds, Marshall and Horne, Macon, Georgia
National Electrical Safety Code

Southwire, Carrollton, Georgia
Power Cable Corona Testing Apparatus Design

Dayton-Granger Aviation, Inc., Fort Lauderdale, Florida
Matching Aircraft Antennas

Marconi Space and Defense Systems, Stanmore, England
Radome Analysis Techniques

Naval Coastal Systems Center, Panama City, Florida
Sea Water Electrode Systems

Sanders Associates, Nashua, New Hampshire
Near Field Coupling of Antennas

New Mexico Engineering Research Institute, Albuquerque, New Mexico
Design of Blast Hardened Radome

Northrop Aircraft, Hawthorne, California
Radome Analysis

Harris Corporation, Broadcast Products Division, Quincy, Illinois
Near-Field Antenna Measurement Feasibility

Freeman and hawkins, Atlanta, Georgia
Transformer Protection

RESEARCH CONTRACTS/GRANTS -- PRINCIPAL/CO-PRINCIPAL INVESTIGATOR

1. "Radome Effects on the Performance of Ground Mapping Radar,"
   U. S. Army Missile Command, Huntsville, Alabama
   E. B. Joy and G. K. Huddleston
   $34,000
   Duration: 1 year
   March 7, 1972 - March 6, 1973

2. Extension of: "Radome Effects on the Performance of Ground Mapping Radar"
   U. S. Army Missile Command, Huntsville, Alabama
   E. B. Joy and G. K. Huddleston
   $5,000
   Duration: 5 months
   March 7, 1973 - August 6, 1973

3. "An Investigation of the Accuracy of Far-Field Radiation Patterns Determined from Near-Field Measurements"
   U. S. Army Missile Command, Huntsville, Alabama
   E. B. Joy and G. P. Rodrigue
   $58,000
   Duration: 14 months
   June 1, 1972 - August 1, 1973

4. "Analysis and Evaluation of Radome Materials and Configurations for Advanced RF Seekers"
   U. S. Army Missile Command, Huntsville, Alabama
   G. K. Huddleston, E. B. Joy and H. L. Bassett
   $30,000
   Duration: 8 months
   April 27, 1973 - December 31, 1973

5. "Measurement and Analysis of the Electromagnetic Coupling to Underground Structures"
   USAF Aerospace Defense Command, Colorado Springs, Colorado
   E. B. Joy
   $303,280
   Duration: 5] years
   July 1, 1972 - December 31, 1977

6. "A Study of Phased Array Antenna Patterns Determined by Measurements on a Near-Field Range"
   U. S. Army Missile Command, Huntsville, Alabama
   E. B. Joy and G. P. Rodrigue
   $100,000
   Duration: 14 months
   December 11, 1973 - February 11, 1975

7. "Multi-Purpose Missile (MPM) High Performance Trade-Off Development"
   Martin Marietta Aerospace Company, Orlando, Florida
   G. K. Huddleston and E. B. Joy
   $21,000
   Duration: 5 months
   July 1, 1974 - December 1, 1974

8. "Near-Field Data Handling Techniques and Probe Design Considerations"
   U. S. Army Missile Command, Huntsville, Alabama
   G. P. Rodrigue, C. P. Burns, E. B. Joy and G. K. Huddleston
   $14,667
   Duration: 10 months
   June 13, 1975 - April 15, 1976

9. "A High Current Minesweeping Electrode Investigation"
   U. S. Naval Coastal Systems Laboratory, Panama City, Florida
   E. B. Joy and R. F. Hochman
   $30,000
   Duration: 7 months
   March 1, 1976 - September 30, 1976

10. "Develop a Computer Program to Calculate Earth Potentials Due to Faults on URD Cable or Loss of Concentric Neutral"
    Electric Power Research Institute, Palo Alto, California
    E. B. Joy, H. N. Nunnally and R. P. Webb
    $70,751
    Duration: 14 months
    March 1, 1976 - April 30, 1977

11. "A Laboratory Testing and Electromagnetic Analysis Program for Carbon Polymer Jacketed and Platinum Plated Minesweeping Electrodes"
    U. S. Naval Coastal System Laboratory, Panama City, Florida
    R. F. Hochman and E. B. Joy
    $44,982
    Duration: 6 months
    July 24, 1976 - January 31, 1977

12. "Development of Fabrication and Processing Techniques for Laser Hardened Missile Radomes"
    Martin Marietta Aerospace Company, Orlando, Florida
    G. K. Huddleston and E. B. Joy
    $17,242
    Duration: 13 months
    August 13, 1976 - September 13, 1977

13. "Final Design and Analysis of High Current Minesweeping Electrodes"
U. S. Naval Coastal Systems Laboratory, Panama City, Florida
E. B. Joy and R. F. Hochman
$53,895
Duration: 1 year
January 26, 1977 - January 31, 1978

14. "A Feasibility Study of Nobel Metal Coated Graphite - Conductive Polymer Materials for Minesweeping Electrodes"
U. S. Naval Coastal Systems Center, Panama City, Florida
R. F. Hochman and E. B. Joy
$34,914
Duration: 12] months
August 15, 1977 - August 31, 1978

15. "LMS Electrode Feasibility Study"
U. S. Naval Coastal Systems Center, Panama City, Florida
R. H. Hochman and E. B. Joy
$42,132
Duration: 4] months
February 10, 1978 - June 30, 1978

16. "Accuracy of Radiation Patterns Determined from Spatially Limited Near-Field Measurements"
National Science Foundation, Washington, D. C.
E. B. Joy
$49,415
Duration: 2] years
July 1, 1978 - February 28, 1981

17. Analytical Compensation for Near-Field Probe Positioning Errors in Calculated Far-Field Antenna Patterns"
U. S. Army Research Office, Durham, North Carolina
E. B. Joy
$82,475.80
Duration: 2 years
July 1, 1978 - June 30, 1980

18. "Graphical and Tabular Results of Computer Simulation of Faulted URD Cables"
Electric Power Research Institute, Palo Alto, California
A. P. Meliopoulos, E. B. Joy and R. P. Webb
$69,000
Duration: 1 year
July 15, 1978 - July 14, 1979

19. "Design Study for High Current Magnetic Minesweeping "S" Cable"
Naval Coastal System Center, Panama City, Florida
E. B. Joy and R. F. Hochman
$59,994
Duration: 8] months
August 9, 1978 - April 20, 1979

20. "Underground Cable Test Simulation and Analysis"
    Florida Power and Light Company, Miami, Florida
    R. P. Webb, A. P. Meliopoulos and E. B. Joy
    $24,927
    Duration: 16 months
    January 1, 1979 - April 30, 1980

21. "Computer Simulation of Cylindrical Surface Near-Field Measurement System Errors"
    Scientific Atlanta, Inc., Atlanta, Georgia
    E. B. Joy
    $5,000 (Fellowship for Graduate Student)
    Duration: 1 year
    October 1, 1978 - September 30, 1979

22. "Development of High Current Conductive Polymer Minesweeping Electrodes"
    Naval Coastal Systems Center, Panama City, Florida
    R. F. Hochman and E. B. Joy
    $63,258
    Duration: 11 months
    January 25, 1979 - December 21, 1979

23. "Modified S-3 Nobel Metal Feasibility Anode Study"
    Naval Coastal Systems Center, Panama City, Florida
    E. B. Joy and R. F. Hochman
    $37,975
    Duration: 8 months
    July 23, 1979 - May 1, 1980

24. "Position Error Compensation for Spherical Surface Near-field Measurements," Scientific Atlanta, Inc., Atlanta, Georgia
    E. B. Joy
    $5,000 (Fellowship for Graduate Student)
    Duration: 1 year
    January 1, 1980 - December 31, 1980

25. "Theory and Applications of Electromagnetic Measurements,"
    Joint Services Electrics Program
    E. B. Joy
    $44,00
    Duration: 11 months
    February 15, 1980 - January 14, 1981

26. "Special Reserch Equipment: Automated Radiation Laboratory"
    National Science Foundation
    G. K. Huddleston, E. B. Joy, W. M. Leach
    $116,403
    Duration: 17 1/2 months
    February 15, 1980-July 31, 1981

27. "Transmission Grounding"
    Electric Power Research Institute, Palo Alto, California
    E. B. Joy, A. P. Meliopoulos and R. P. Webb
    $165,413
    Duration: 1 year 8 months
    October , 1980 - July 1, 1982

28. "Conductive Polymer Development for Minesweeping Electrode Jackets"
    Naval Coastal Systems Center, Panama City, Florida
    E. B. Joy and R. F. Hochman
    $119,856
    Duration: 14 months
    September 9, 1980 - October 30, 1981

August 1981

BIOGRAPHICAL SKETCH

HUDDLESTON, GENE K. -- Associate Professor
School of Electrical Engineering
Georgia Institute of Technology

EDUCATION

BEE, Georgia Institute of Technology
MSEE, Georgia Institute of Technology
Ph.D. in EE, Georgia Institute of Technology

EMPLOYMENT HISTORY

Georgia Power Company, Atlanta, Georgia	
Co-op Student	1960-1963
U.S. Marine Corps	
Reconnaissance Officer and Technical Writer	1964-1968
Georgia Institute of Technology	
Graduate Research Assistant	1968-1970
Research Engineer	1970-1972
Instructor, Electrical Engineering	1972-1977
Lecturer, Electrical Engineering	1977-1978
Assistant Professor, Electrical Engineering	1978-1981
Associate Professor, Electrical Engineering	1981-Present

EXPERIENCE SUMMARY

As co-op student with Georgia Power Company, worked in steam-electric generating plant in instrumentation section and later as draftsman in transmission substation's section of electrical engineering department. As Marine officer, served as reconnaissance officer and troop leader and afterwards as correspondence course writer, supervisor of other course writers, and as ceremonial platoon leader. As graduate research assistant at Georgia Tech, worked on radome design techniques at millimeter wavelengths utilizing dielectric lenses and leaky wave antennas in radiant configurations. As research engineer, worked on determining high temperature dielectric properties of radome materials at X- and K-band frequencies and the instrumentation and computer programming required in this work; worked on radome sidelobe reduction techniques at X-band frequencies using anisotropic structures; worked on pyroelectric probe for microwave dosimetry applications; studied effects of microwave radiation on enzymes; worked on development of broadband electromagnetic window structure; worked on remote data acquisition system for pollution sensors; served as project director. As faculty member in the School of Electrical Engineering worked on radome analysis and design, lightning protection for solid state circuits, near-field antenna measurements, served as research project director; taught courses in digital system design and interfacing small computers, and advanced electromagnetic theory; served as chairman of faculty committees; established automated radiation laboratory for electromagnetics research..

CURRENT FIELDS OF INTEREST

Antennas, radomes, lightning protection for solid state circuits, near-field/far-field transformations.

MAJOR REPORTS AND PUBLICATIONS

1. "Millimeter Radome and Antenna Techniques," U.S. Air Force Nineteenth Antenna Symposium, October 1969, co-author.

2. "Millimeter Radome Design Techniques," Technical Report AFAL-TR-70-163, U.S. Air Force Contract F33615-68-C-1193, August 1970, co-author.

3. "Inorganic Nose Cone Techniques for Sidelobe Reduction," Technical Report AFAL-TR-71-172, U.S. Air Force Contract F33615-70-C-1237, July 1971, co-author.

4. "Electrical Design Data for Navigation Buoys," Technical Report No. 2, U.S. Coast Guard Contract DOT-CG-10657-A," June 1971, co-author.

5. "Radome Design Using Dielectric Gratings," U.S. Air Force Twenty-First Antenna Symposium, October 1971.

6. "High Temperature Complex Permittivity Measurements on Reentry Vehicle Antenna Window Materials," Technical Report No. AFWL-TR-71-189, U.S. Air Force Contract F29601-70-C-0069, April 1972, co-author.

7. "Studies of Microwave Dosimetry," Purdue 1972 Symposium on Electromagnetic Hazards, Pollution, and Environmental Quality, May 1972, co-author.

8. "Investigation of Electromagnetic Radiation on Enzymes," Purdue 1972 Symposium on Electromagnetic Hazards, Pollution, and Environmental Quality, May 1972, co-author.

9. "Study of Microwave Dosimetry," Technical Report No. 1, National Institute of Health Contract NIH-71-2374, August 1972, co-author.

10. "Broadband Panel Design," Eleventh Symposium on Electromagnetic Windows, August 1972, co-author.

11. "Broadband Radome Techniques," Interim Technical Report No. 1, Contract No. F33615-71-C-1694, February 1973, co-author.

12. "Radome Effects on the Performance of Ground Maping Radar," Final Technical Report, Contract No. DAAH01-72-C-0598, March 1973, co-author.

13. "Study of Microwave Dosimetry," Technical Report No. 2, National Institute of Health Contract No. NIH-71-2374, June 1973, co-author.

14. "Radome Effects on the Performance of Ground Mapping Radar," Technical Report No. 2, Contract No. DAAH01-C-0598, August 1973, co-author.

15. "Effects of Microwave Radiation on Enzymes," 1973 IMPI Symposium on Microwave Power, Loughborough, England, September 1973, co-author.

16. "Analysis and Evaluation of Radome Materials and Configurations for Advanced RF Seekers," Final Technical Report, Contract No. DAAH01-73-C-0769, December 1973, co-author.

17. "A Pyroelectric Prove for Measurement of Microwave Power Density Under Far-Field Conditions," Conference on the Biological Effects of Non-Ionizing Radiation, February 1974, co-author.

18. "FAA Lightning Protection Study: Lightning Protection Requirements for the AN/GRN-27(v) Instrument Landing System," Final Technical Report, Contract No. F30602-73-C-0409, April 1974, co-author.

19. "FAA Lightning Protection Study: Lightning Protection Requirements for Mark III Instrument Landing System (Category III)," Final Technical Report, Report No. FAA-RD-75-73, February 1975, co-author.

20. "A Study of Phased Array Antenna Patterns Determined by Measurements on a Near-Field Range," Final Technical Report, U.S. Army Missile Command, March 1975, co-author.

21. "Multi-Purpose Missile (MPM) High Performance Radome Trade-Off and Development Study," Martin-Marietta Aerospace Division, Final Technical Report, April 1975, co-author.

22. "Lightning Protection for Status and Control Lines of the Mark III Instrument Landing System," presented at FAA Workshop on Grounding, Bonding, and Shielding, Atlanta, Georgia, May 1975; Annual Meeting of Institute of Navigation, Washington, D.C., June 1975; 1975 IEEE International Symposium on Electromagnetic Compatibility, San Antonio, Texas, October 1975.

23. "FAA Lightning Protection Study: Lightning Protection Measurements for Airport Surveillance Radar Model ASR-7," Final Technical Report No. FAA-RD-75-180, July 1975, co-author.

24. "FAA Lightning Protection Study: Circuit Modifications for Mark III Instrument Landing System to Prevent Operational Upsets Due to Electrical Transients on Cables," Final Technical Report No. FAA-RD-76-61, February 1976.

25. "A Study of Near-Field Data Handling and Probe Design Techniques," Final Technical Report, U.S. Army Missile Command, April 1976, co-author.

26. "A High-Current Minesweeping Electrode Investigation," Final Technical Report for Naval Coastal Systems Laboratory, June 1976.

27. "Development of Fabrication and Processing Techniques for Laser Hardened Missile Radomes: Radome Electrical Design Analysis," Final Technical Report, Martin-Marietta Aerospace, April 1977.

28. "Electromagnetic Pulse Coupling to Underground Systems," Final Technical Report, Aerospace Defense Command, December 1977, co-author.

29. "Parametric Investigation of Radome Analysis Methods," 1978 International IEEE Symposium Digest, Antennas and Propagation, pp. 199-202, May 1978, co-author; also in Proceedings of the Fourteenth Symposium on Electromagnetic Windows, pp. 21-28, June 1978, co-author.

30. "Optimum Probes for Near-Field Antenna Measurements on a Plane," Ph.D. Dissertation, Georgia Institute of Technology, Atlanta, Georgia, 1978.

31. "Parametric Investigation of Radome Analysis Methods," Annual Reports, Grant AFOSR-77-3469, November 1978 and February 1980, co-author.

32. "Radome Analysis Computer Program: Ray Tracing Formulation," Final Report, Johns Hopkins University Applied Physics Laboratory, November 1979.

33. "Aperture Synthesis from Principal Plane Patterns of Monopulse Antenna for Radome Analysis," 1980 International IEEE/AP-S Symposium Digest, pp. 338-341, June 1980.

34. "Results of Parametric Investigation of Radome Analysis Methods," Proceedings of Fifteenth Symposium on Electromagnetic Windows, pp. 30-33, June 1980, co-author.

35. "A Generalized Ray Tracing Method for Single-Valued Radome Surfaces of Revolution," Proceedings of Fifteenth Symposium on Electromagnetic Windows, pp. 44-50, June 1980, co-author.

36. "Radome Effects on Polarimetric Processing Seekers," Final Report, U. S. Army Missile Command, June 1980, co-author.

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